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PARTIAL MELTING OF THE ST. SEVERIN (LL) AND LOST CITY (H) ORDINARY CHONDRITES: ONE STEP BACKWARDS AND TWO STEPS FORWARD; A.J.G. Jurewicz, J. H. Jones*, D.W. Mittlefehldt: Mail Code C23, LESC, PO Box 58561, Houston, TX 77258; *SN4 NASA/Johnson Space Center, Houston TX 77058✓

This study looks at partial melting in H and LL chondrites at near one atmosphere total pressure as part of a continuing study of the origins of basaltic achondrites. Previously, melting experiments on anhydrous CM and CV chondrites showed that, near its solidus, the CM chondrite produced melts having major element chemistries similar to the Sioux County eucrite; but that pyroxenes in the residuum were too iron-rich to form diogenites [1]. Our preliminary results from melting experiments on ordinary (H, LL) chondrites suggested that, although the melts did not look like any known eucrites, pyroxenes from these charges bracketed the compositional range of pyroxenes found in diogenites [2]. We had used the Fe/Mg exchange coefficients calculated for olivine, pyroxene and melt in these charges to evaluate the approach to equilibrium, which appeared to be excellent. Unfortunately, mass balance calculations later indicated to us that, unlike our CM and CV charges, the LL and H experimental charges had lost significant amounts of iron to their (Pt or PtRh) supports. Apparently, pyroxene stability in chondritic systems is quite sensitive to the amount of FeO, and it was this unrecognized change in the bulk iron content which had stabilized the high temperature, highly magnesian pyroxenes of [2]. Accordingly, this work re-investigates of the phase equilibria of ordinary chondrites, eliminating iron and nickel loss, and reports significant differences from [2]. It also looks closely at how the iron and sodium in the bulk charge affect the stability of pyroxene, and comments on how these new results apply to the problems of diogenite and eucrite petrogenesis.

Experimental: Powdered, chemically-characterized silicate separates of Lost City (H) and St. Severin (LL) chondrites were obtained from E. Jarosewich (Smithsonian Inst., NMNH). A synthetic metal fraction, comprised of fine Ni and Fe powders using the composition of [3], was mixed with the silicate to complete our starting material.

Pressed pellets of starting material (~110 mg) were "spot-welded" onto Pt or Pt-40%Rh loops. These loops had previously been doped with iron and nickel by equilibrating them with a simulated H-chondrite at high temperatures for 4-7 days. The charge was then run isothermally, under a controlled oxygen fugacity (fO_2), for between 3-5 days and, finally, drop-quenched into de-ionized water.

The furnace fO_2 was set at IW-1 (one log unit below the iron-wüstite buffer) using appropriately mixed flowing CO/CO₂ gas. Target temperatures were between 1170° and 1350°C. Since the charges were open to the gas stream, volatiles were lost. Rapid loss of the volatiles early in the run reduced the volatile-content of each charge to a low, metastable value, so that the final concentration of volatile elements depended primarily on the initial charge composition and run temperature, not run duration. Details for this technique are given in [1].

Results: All charges contained melt, olivine, and metal, ±low calcium pyroxene, ±chromite, and ±sulfide. Melts plotted near the Ol-Py-Pl peritectic point used by [4] to describe eucritic melts. Even at the lowest temperature, 1170°C, charges contained 10-15% melt, and neither plagioclase nor a high-calcium pyroxene was observed. Figure 1 gives the calculated abundances for each silicate phase and metal as a function of temperature.

Several of the lower temperature charges retained a significant amount of sodium (melts having 1-2 wt% Na₂O; open circles in Figure 1). Melts from these charges were all consistently more plagioclase and pyroxene normative than their corresponding low-sodium counterparts, being more siliceous and having lower CaO/Al₂O₃ ratios. Consequently, the modal abundance of pyroxene in these charges was smaller (c.f., [5] and Figure 1). The other volatile showing significant variability, sulfur, did not measurably affect the silicate phase equilibria.

The effect of bulk iron on these systems can be seen in part in Table 1, which compares results from 1275°C and 1325°C Lost City charges [this study, 2]. Because bulk iron was not lost during this study, Mg#s for melt, olivine and pyroxene in the new charges were generally lower than previously reported [2]. In general, the differences were in (1) the phase abundances observed at each temperature and (2) the pyroxene disappearance temperature. Specifically, an increase in the bulk iron corresponded with a decrease in the amount of pyroxene, a corresponding increase in the amount of olivine, and a slight increase in the amount of metal in the residue; however, the amount of melt observed was basically unchanged. In [2], pyroxene was present at all temperatures, persisting even at 1325°C. In contrast, in this study, pyroxene disappeared at lower temperatures: at ~1220°C in Lost City (Wo₂ En₆₆ Fs₃₂); just above 1328°C in St. Severin (Wo₁ En₇₅ Fs₂₄).

Implications for Eucrite and Diogenite Petrogenesis: Although the conclusions of [2] need to be revised slightly, the gist of the arguments remain intact. Melting of CM, CV, H and, by inference, CO chondrites leaves a residue that is dominated by olivine, making these chondrites poor candidates for the parent material of diogenites.

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However, our 1180°C Murchison partial melts had major element contents within 3% of those measured for Sioux County, and melts of Allende at 1180°C were similarly close to Ibitira [1]. Conversely, the LL chondrites may have sufficient pyroxene in the residuum to produce diogenites and, above ~1200°C, St. Severin pyroxenes have CaO and Al₂O₃ abundances (0.5-2 wt% CaO; 0.5-1 wt% Al₂O₃) which overlap those in diogenitic pyroxenes [7]. However, their low temperature melts do not closely resemble any of the main group eucrites.

Thus, the long-standing problem of relating diogenites and eucrites remains unresolved. Currently, CO or CM chondrites appear to be the best choices for producing eucrites [6], but a more siliceous composition (e.g., LL chondrites) seems necessary for the production of diogenites. The CaO and Al₂O₃ abundances in St. Severin pyroxenes reinforce the idea that the diogenites crystallized from a parent with chondritic relative abundances of these elements [9]; and the LL pyroxenes which have Mg#s approaching that of the average diogenitic pyroxene (~74) also have an appropriate CaO content (~1.0-1.5 wt% vs. ~1.2 wt% for diogenites). However, the match in Mg# is tenuous. Since the Mg# of ~74 for diogenitic pyroxene is an average value, and since only our highest temperature pyroxenes have Mg#s ~74-75, then the average Mg# for the entire suite of experimental pyroxenes (~70-71) is too low to produce diogenites. One way to attain a higher overall Mg# is to remove FeO from the silicate system by increasing the amount of Fe⁰; e.g., by lowering the fO₂. This could mean that the diogenite parent was similar to an LL chondrite, but slightly more reduced than in our experiments (~IW-1.5 vs. ~IW-1).

Regardless, we have yet to demonstrate that one natural chondrite composition can produce both eucrites and diogenites in a single petrogenetic scenario that elegantly conforms to all of the geochemical constraints. The lack of a unifying model is worrisome, as there is physical evidence that both lithologies coexist on a single, small body.

References: [1] Jurewicz et al. (1993) *GCA* 57 2123-2139; [2] Jurewicz et al. (1993) *LPSC XXIV* 739-740 (abst.); [3] Jaroswich (1990) *Meteoritics* 25 323-337; [4] Stolper (1977) *GCA* 41 587-611; [5] McGuire et al. (1994) *LPSC XXV*, this volume; [6] Jones et al. (1994) *LPSC XXV*, this volume; [7] Mittlefehldt (1994) *GCA*, in press; [9] Jurewicz et al. (1994) in preparation.

Figure 1. Calculated modal abundances for silicates and metal in St. Severin and Lost City. Data from 1325°C charges which gained or lost FeO, and from charges which retained more than 1 wt% Na₂O in the melt, are given as open symbols.

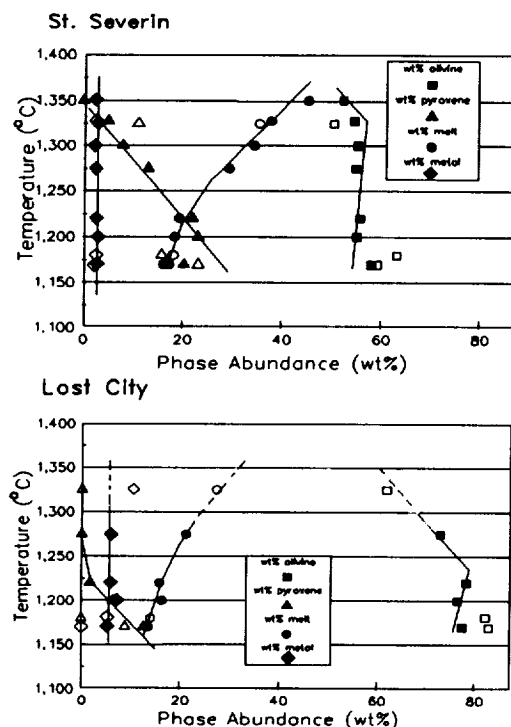


Table 1. Melt compositions, Mg#, and the silicate phase assemblages for pairs of Lost City charges (one low bulk iron; one relatively unchanged) at two temperatures. Note: decreased FeO stabilizes pyroxene.

Temperature	1325	1325	1275	1275
Status of Bulk Fe ⁰	small iron gain (~6%)	iron loss (~40%)	no measurable loss or gain	iron loss (~35%)
Silicate phase assemblage	ol-melt	ol-melt-low calcium pyroxene	ol-melt	ol-melt-low calcium pyroxene
SiO ₂	44.92	50.94	47.18	50.79
TiO ₂	0.26	0.27	0.31	0.39
Al ₂ O ₃	7.00	7.25	8.30	11.02
FeO	31.06	20.36	28.24	17.33
MnO	0.37	0.46	0.35	0.42
MgO	11.24	13.72	9.52	11.27
CaO	5.42	5.83	6.34	8.07
Na ₂ O	0.03	0.01	0.01	0.06
Cr ₂ O ₃	0.74	0.79	0.67	0.67
Total	101.05	99.65	101.04	100.05
Mg#	39.21	54.56	37.54	53.69
CaO/Al ₂ O ₃	1.41	1.46	1.39	1.33
ol/mK _D Fe/Mg	0.34	0.35	0.35	0.37
py/mK _D Fe/Mg	—	.29	—	.33

* all iron as FeO.